

MONANA

JOURNAL
of the
AUSTRALIAN
METEOROLOGICAL
ASSOCIATION

THE AUSTRALIAN METEOROLOGICAL ASSOCIATION

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AUSTRALIAN METEOROLOGICAL ASSOCIATION (INC.)

PRESIDENT'S REPORT - 7th June, 1979

We have just completed our tenth year as an Association and, although no great advances were made, membership and attendances have been maintained at approximately the same levels as for the previous year. During the 1978/79 year there have been 2 new members, 4 resignations and one death, giving an overall reduction of three. The Association has recorded the death of Mr. F. J. Hall and has sent a letter of sympathy to Mrs. Hall.

The programme of speakers over the past twelve months has been as follows:-

- 6th June, 1978 - A.G.M. and Mr. A. Brunt - "Popular Misconceptions about the Weather"
- 3rd August, 1978 - Mr. L. Mitchell - "Meteorological Optics"
- 3rd October, 1978 - Chart drawing and films
- 30th November, 1978 - Dr. A. Beresford - "New fields of Astronomy"
- 6th February, 1979 - Mr. L. Beadell - "Too long in the bush"
- 5th April, 1979 - Mr. & Mrs. R. Sprigg - "Exploring the Simpson Desert"

There were quite small attendances at some of these meetings, but the Len Beadell and Sprigg nights were well attended. This leads to the conclusion that there is a preference for well-known speakers or talks of this type, even though they had little meteorological content. Whichever is the case, there is a definite need for members to communicate with the Committee to let them know their preferences with regard to future speakers.

We should not forget that visitors are welcome at any of our meetings and members are encouraged to bring husbands/wives or etceteras. With the agreement of Australia Post, our notices of meetings are now being displayed in the Weather section of the G.P.O. Notice Board. Also, our Secretary has arranged for details about

meetings to be included in the Advertiser and also broadcast on the radio; there is no doubt that these methods give rise to some of the visitors. It is up to every member, however, to encourage attendance at meetings for this is the way that organisations are maintained.

Our financial position remains quite sound, especially since we have sought a cheaper method of publishing "Monana". Unfortunately, this has caused a considerable delay in the publication of this magazine, but it also means that there is no need to increase subscription rates and we can continue with the basic \$5 per annum.

Members owe a debt of gratitude to Mr. R. J. Whatmough who takes notes and summarises our talks for later publication in "Monana". My thanks are due to the Committee members for their assistance during the year and especially to Mrs. J. Bannister, our Secretary/Treasurer, who does such a fine job behind the scenes.

A. T. BRUNT
President

THE 1977-78 ADELAIDE SUMMER

G. Vecchio

S.A. Regional Office, Bureau of Meteorology.

Introduction

The Adelaide 1977-1978 summer was cooler and drier than normal. This can be directly attributed to the general wind pattern prevailing over southern Australia.

During much of the summer Adelaide was under the influence of a ridge of high pressure emanating from a large semi-permanent high in the south-east Indian Ocean. Winds in Adelaide were generally cool and from the south-west to south. This high, on occasion, retracted a little westwards allowing fronts of southern origin to move into the south-west corner of Western Australia. At the same time a small high generally formed over waters south of the Great Australian Bight. The Bight high, however, was migratory and moved eastwards along the South Australian coast and eventually amalgamated with the semi-permanent high in the Tasman Sea; and, winds in Adelaide tended more south-east to east. The fronts over the south-west of Western Australia usually weakened as they progressed eastwards and steered to the south-east around the intensifying Tasman Sea high. As the fronts weakened, Adelaide came under more direct influence of a ridge extending from the high in the Tasman Sea. Conditions became warmer as winds turned north-easterly. These warmer conditions, however, did not last long because fronts, of Southern Ocean origin, did in time erode the ridge and reached Adelaide. These fronts were usually weak and produced little, if any, precipitation; but they did manage to maintain lower temperatures.

Note Concerning the Adelaide Data

On February 3, 1977 the Adelaide office of the Commonwealth Bureau of Meteorology moved from West Terrace to its new premises at College Road, Kent Town. While observations are still being made at West Terrace - for comparison purposes - official temperatures for Adelaide are now read at the Kent Town site. The data used in this work, unless otherwise stated, refer to the Kent Town site.

Summer Temperatures

From October 1, 1977 to April 30, 1978 there were only 45 occurrences when the official maximum temperature T , exceeded or equalled 30°C ; i.e. $T \geq 30^{\circ}\text{C}$. West Terrace recorded 42 occurrences. Table 1 gives the number of days in each month for which $T \geq 30^{\circ}\text{C}$; those for West Terrace are in brackets.

Table 1 Number of days during which the official maximum temperature exceeded or equalled 30°C ; those for West Terrace are in brackets.

1977	October	5	(5)
	November	5	(4)
	December	11	(11)
1978	January	6	(6)
	February	10	(7)
	March	7	(8)
	April	1	(1)
Totals:		45	(42)

The lowest maximum temperature for each month is given in Table 2.

Table 2 Lowest maximum temperatures each month

	Kent Town	West Terrace
1977 October	15.8°C (on 19th)	15.6°C (on 19th)
November	17.1°C (on 5th)	17.0°C (on 11th)
December	19.4°C (on 27th)	19.0°C (on 27th)
1978 January	20.0°C (on 28th)	20.2°C (on 28th)
February	21.2°C (on 11th)	21.6°C (on 11th)
March	17.9°C (on 31st)	17.6°C (on 26th)
April	16.6°C (on 1st)	16.7°C (on 26th)

The highest maximum recorded for the summer was 39.3°C on January 14; for West Terrace 38.5°C - same day.

The number of occasions in which for two or more consecutive days the official maximum temperature exceeded or equalled 30°C is given in Table 3.

Table 4

	ADELAIDE		MELBOURNE		PERTH		SYDNEY		HOBART		CANBERRA	
	Observed Av. °C	Departure °C	Observed Av. °C	Departure °C	Observed Av. °C	Departure °C	Observed Av. °C	Departure °C	Observed Av. °C	Departure °C	Observed Av. °C	Departure °C
Dec 1977	27.1	-0.7	23.7	-0.4	30.7	+3.4	26.9	+2.0	19.6	-0.6	28.3	+2.3
Jan 1978	26.5	-3.0	24.0	-1.8	33.3	+3.8	26.2	+0.5	21.9	+0.5	26.5	-1.0
Feb 1978	27.1	-2.3	24.7	-1.1	31.9	+2.0	28.4	+3.0	21.0	-0.5	28.8	+2.2

Table 3 Number of occasions on which for two or more consecutive days $T \geq 30^{\circ}\text{C}$.

Number of Consecutive Days	Frequency	Number of Days
2	8	16
3	4	12
4	1	4
5	1	5
Totals:		37

Defining a hot spell as a period when for two or more consecutive days the maximum temperature exceeded or equalled 30°C , it can be seen from Table 3 that most hot spells lasted only two or three days. The longest spell (five days) occurred from March 7 to 12.

Table 4 lists the average observed maximum temperature and the departure from its long term average for the capital cities of southern Australia. It can be seen that temperatures were below normal in Adelaide and Melbourne, above average for Perth, Sydney and Canberra, and near normal for Hobart.

Again, these departures from average conditions can be directly explained in terms of the prevailing wind circulation. For example, the cooler than average temperatures in Adelaide, and also Melbourne, resulted from the prevailing airstream which was mainly of a southern origin. By contrast, the above average temperatures for Perth were produced by a predominantly overland north-easterly airstream.

Table 5 is a frequency analysis of the official Adelaide maximum temperatures during December 1977 and January, February, 1978. The table indicates that for more than one day in three, the maximum temperature was in the range between 20.1°C and 25.0°C .

Table 5 Frequency analysis Adelaide maximum temperature from December 1, 1977 to February 28, 1978. (90 days)

Maximum Temperature Range, °C	Frequency
≤ 20	4
20.1 - 25.0	33
25.1 - 30.0	26
30.1 - 35.0	20
35.6 - 40.0	7
Totals:	90

Summer Rainfall

During the summer of 1977-1978 the amount of rainfall recorded at Adelaide was significantly below normal- see Table 6. In the seven months to April 30, 1978 the amount of rainfall deficit amounted to 46.8 mm.

Table 6 Adelaide recorded rainfall October 1977 - April 1978, long term average and departure from means.

	Recorded mm.	Average mm.	Departure mm.
1977 October	47.0	45	+ 2.0
November	37.2	31	+ 6.2
December	15.2	26	-10.8
1978 January	2.6	20	-17.4
February	6.8	21	-14.2
March	9.0	24	-15.0
April	46.6	44	+ 2.6
Totals:	164.2	211	-46.8

The total rainfall for the summer months (December, January, February) was only 24.4 mm.; amount at West Terrace, 24.8 mm. This was the lowest rainfall since the summer of 1964-65 when 23 mm. was recorded. Some other low rainfall summers were:- 1963-64 (20 mm.) and 1960-61 (16 mm.); the lowest on record is 4 mm. for the summer 1905-06.

ACKNOWLEDGEMENTS

I am indebted to the South Australian Regional Office of the Australian Bureau of Meteorology for the provision of the data used in this study.

THE JAPANESE GEOSTATIONARY METEOROLOGICAL SATELLITE

G. Vecchio

S.A. Regional Office, Bureau of Meteorology

Introduction

The Japanese geostationary meteorological satellite (GMS) monitors weather conditions over Japan, Australia and adjacent areas - see Fig. 1. It was launched by NASA on July 14, 1977 from Cape Canaveral and is now in position over the equator at 140°E longitude. The satellite - at an altitude of 36000 km - is spin stabilized with a spin rate of about 100 revolutions per minute; the axis of revolution being parallel with that of the earth. The GMS is mounted with a visible and infrared spin scan radiometer (VISSR) which scans the earth's disc in approximately 25 minutes (2500 revolutions).

The satellite is held in position by three ground stations in Japan, Thailand and Australia. The Australian station is at Orroral Valley near Canberra.

The GMS and its Missions

The GMS can be used to interrogate ocean buoys and atmospheric balloons drifting in remote areas well beyond the range of normal communication. In addition, information from ships and automatic weather stations can be gleaned and relayed to data acquisition centres. However, the main mission of the satellite is threefold, namely:-

- (i) To radiometrically scan the earth at both visual and infra red frequencies, to digitize the output and to transmit the digitized output - in real time - to the Control Data Acquisition Station (CDAS) in Japan.
- (ii) In Japan the digitized data is conveyed to a Data Processing Centre (DPC) where imagery of the disc is made. The imagery is electronically synchronized and the outlines of the land masses are dotted. Additionally grid lines are added. The full

disc picture has a resolution- at sub-satellite point - of 2.6 km in the visual range and 5.0 km in the infra red. The full disc can be enlarged and sectorized. Seven low resolution pictures are made from the full disc - see Fig. 2; of these, sectors F and G covers Australia. Sector F and G have a resolution of approximately 4 km in the visual and 6.5 km in the IR.

- (iii) The full disc imagery and its sectorized products are transmitted via satellite to Medium and Small Data Utilization Stations (MDUS and SDUS). Currently Australia has one MDUS.

The Australian MDUS

Australia has installed, at a cost of approximately \$A400,000, an MDUS at the Bureau of Meteorology Head Office in Melbourne. Melbourne receives routine three hourly imageries of full disc and sectors F and G. These are then re-transmitted - via the Bureau national facsimile network - to the various Regional Forecasting Centres (RFC's). More frequent observations - approximately at hourly intervals - are obtained when Australia is threatened by, or is under the influence of, severe weather conditions. Each of the RFC's have their own specified hazardous situations. These include tropical cyclones, and in the case of South Australia, potential bushfire conditions.

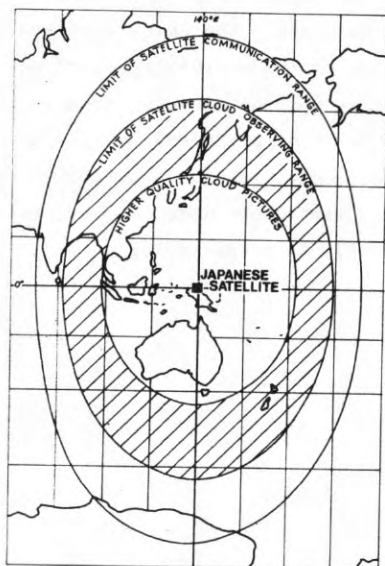
The full disc imagery can be stored and studied. These, in time, could provide a better assessment of the behaviour of weather systems such as tropical cyclones, cold fronts, squall lines, thunderstorms, and because of the more frequent availability of data, the accuracy of the forecasts should increase.

The GMS and GARP

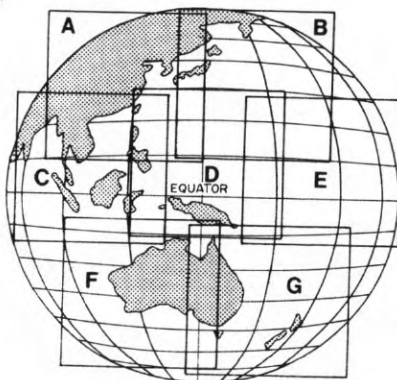
In addition to its direct role in improving weather forecasting for Japan, Australia and adjoining areas, the GMS is part of an international weather research project aimed at improving world weather forecasting. The project, called GARP - Global Atmospheric Research Program - consists of five geostationary satellites in orbit over the equator. The Japanese GMS is one of these; two others are American,

one European and the fifth is from Russia; only the Russian satellite is yet to be launched. The satellites are arranged so as to provide a complete view of the world's tropical and temperate zones.

Additional areas will be surveyed from two Polar orbiting satellites, orbiting the earth at different sense. The whole earth will thus be surveyed. The study aims for a better understanding of the behaviour of the earth's atmosphere and, in time, determine to what extent the atmosphere really is predictable.



COVERAGE OF G.M.S. SATELLITE



Disc Sectors (F and G covers Australia)

SOME METEOROLOGICAL CONSIDERATIONS IN THE DESIGN OF A POWER STATION

Angus Robin

A summary of an address at the August meeting as recorded by
R.J. Whatmough

Three main pollutants from a coal-burning power station were considered. The first of these is fly-ash, the visible "smoke", which should not be confused with water droplets that quickly evaporate. The second is sulphur dioxide. Its concentration varies by a factor as great as 9 according to which part of the coal seam is being mined at the time. The third pollutant is a mixture of nitrogen oxides, NO_x to the chemists or "nox" for short.

Precipitators in the chimneys remove 90% of the fly-ash, but do not affect the other materials. The more power that is generated, the more of the pollutants there will be.

The chimney plume interacts with the air in various ways and often part of it reaches ground level. The aim of the study was to find how high a chimney needs to be to keep down the amount of pollution that reaches the ground, without its being unnecessarily expensive.

The Trust collects a lot of detailed meteorological data and some of these were combined with more general data collected by the Bureau. The detailed measurements revealed many interesting patterns and the Bureau staff found it hard not to be distracted from the relevant facts. Sadly, the data belong to the Trust and are not likely to be made public.

The behaviour of the plume depends on the stability of the air at different heights. In well-mixed air the temperature falls at a certain rate (the adiabatic rate) with height and the air has "neutral" stability. If temperature falls more sharply, after heating by the ground say, the air is "unstable"; if temperature falls more slowly with height, remains constant or increases, the air is "stable". Alternate heating and cooling of the ground usually produce two or more layers with different characteristics. An "inversion" is a very stable layer.

A plume in unstable air tends to wave up and down, and waves growing into large billows away from the chimney; the plume is said to be "looping". In neutral air it gradually spreads out, forming a "cone". In stable air it will spread only horizontally, forming a "fan". If there are two layers of different stabilities near the chimney top, interesting combinations can result. An unstable layer above and a stable layer below produce a plume with a flat base and billows above like a cumulus cloud; this plume is said to be "lofting". The reverse produces downward billows only; the plume is then "fumigating" and its effects on the ground are as bad as they sound.

Wind is also important - a strong wind tends to bring the plume closer to the ground, a weak breeze lets it rise.

In practical calculations, the different kinds of plume are difficult to handle. In the study, the measurements are used to define an "average" plume (shaped somewhat like the cone seen in neutral air) from which ground concentrations are easily calculated. Such methods do not always work - it is the meteorologist's job to make them satisfactory for use.

L. Mitchell

A summary of an address, also at the August meeting, as recorded by
R.J. Whatmough

Light behaviour patterns in the atmosphere have six main causes, namely perspective, reflection, refraction, diffraction, scattering and polarisation. Most involve the sun or moon as light source and many occur only during certain parts of the day.

There are other phenomena not considered optical that need to be considered when strange sightings in the sky are to be explained.

Perspective

In perspective phenomena, nothing unusual is happening to light, but we misinterpret what we see because objects are at unfamiliar distances and angles.

If we look at several clouds at different distances, all of which have flat bases at the same height, the bases of the more distant clouds appear to be lower. Rows of such clouds may seem to have bases rising in steps, forming cloud echelons.

The height of a single flat layer of cloud will be judged differently according to its position in the sky. A long band can appear to be higher in the centre, so we see arching.

Just as a straight road appears to narrow in the distance, parallel sun rays that are visible around a cloud that hides the sun appear to converge with height. We seem to see the rays spreading from a point in the clouds. The same thing happens to auroral "streamers" - they are parallel but seem to diverge.

The sky itself, even when free of clouds, seems to have a saucer shape, flattened in the middle. The illusion is heightened by the real flatness seen on overcast days. It leads in turn to the apparent greater size of the sun and moon when they are near the horizon.

Reflection

The most familiar reflection is that produced by a flat mirror. When light from an object reaches us after reflection by the mirror, we can see the object by the light but in the wrong place and often upside-down.

When light passes between air layers of different temperatures it is bent, and the bending may be sufficient to act like a reflection.

A distant object can then appear at the wrong height or upside down, and will be called a mirage.

Some temperature inversions, in which warm air underlies cold, produce a simple inverted image in the sky of an object on the ground. Other inversions produce an image that is right-way-up; these can make the object visible at abnormally large distances. The lighthouse on Rottneest Is., W.A. is sometimes seen 20 km away in this way.

Islands, seen as mirages over the sea, can appear distorted in many ways. Typical forms are the superior image, in which a right-way-up image and a rather flattened upside-down image float above the horizon attached base to base, and the inferior image, in which only the higher parts of the island appear above the horizon and the same parts appear reflected below it. The first form is caused by an inversion, and the second by a cold surface layer.

In the Straits of Messina near Italy, a famous mirage called the Fata Morgana occurs. A complex multiple image of buildings on the shore makes them look like a "crystal palace".

Refraction

Light rays are bent not only by air layers of different densities but also by the surfaces of water droplets and ice crystals. This bending is known in general as "refraction". Its effects come in endless varieties.

Random fluctuations in air temperatures produce the shimmer seen near the ground on hot days - or over the barbecue on cold days! They also produce the scintillation (twinkling) of stars and planets.

Refraction can change the apparent size of distant objects, to produce effects known as looming, sinking, towering and stooping. Refraction makes the sun look higher at sunrise and sunset. Consequently $1\frac{1}{2}$ minutes of extra sunshine are added to each end of the day at the latitude of Adelaide.

People who study sunsets may also be lucky enough to see a play of colours just as the sun disappears, ending in the so-called green flash. The white light from the sun is a mixture of many colours, and refraction, which bends different colours by different amounts, is able to separate them.

The best-known example of colour separation is of course the rainbow. Light rays entering a raindrop can, among other things,

enter the drop, be reflected from the far side and leave the drop again from the near side. The combination of two refractions and a reflection by the curved surface focuses the rays so that many leave at an angle 42° from those coming in. The exact angle depends on colour. An observer with the sun behind and a sheet of rain in front sees extra light from any drops at a 42° angle from the point directly opposite the sun (the "anti-solar" point). From a mountain he can see a coloured circle, but on the plain only the top part is visible. If the sun is too high, there can be no raindrops in the right places and no rainbow.

Light rays that are reflected more than once within the raindrop before escaping produce similar but weaker bows. Two reflections make a secondary bow at 51° from the anti-solar point (just outside the normal bow).

A lunarbow formed from the moon's light is possible but the colours are hard to find. Fogbows also occur but the fog mixes the colours together again and only white is seen.

Haloes are formed by ice crystals. Because the crystals are hexagonal rather than spherical, many effects are possible, especially if the crystals are lined up in a certain direction. Firstly there are two coloured circles, red nearest the sun, at 22° and 46° from it. Other circles and parts of circles, some produced by reflection rather than refraction, are sometimes visible. The parhelic circle runs through the sun and round the sky horizontally. At various points on the parhelic circle there may be patches of light called parhelia, mock suns or sun dogs. Other arcs touching the two main circles may be visible. The sun itself may sit in a vertical bar of light, the sun pillar. Similar forms can be seen around the moon.

Diffraction

Diffraction is another kind of light-ray bending that occurs near the edges of objects. Like refraction it can separate colours.

Coronas are coloured rings around the sun or moon, caused by diffraction near water droplets. They are coloured, blue being nearest the centre. Irridescent clouds diffract light as it passes around them and are partly lit by the affected light.

The Bishop's Ring is a kind of halo formed by atmospheric dust. It was first noted by Rev. Bishop after the eruption of the volcano Krakatoa.

The glory or anti-corona is formed by diffraction around a large object and may be seen by air travellers as a coloured ring around the aircraft's shadow on the clouds below.

The Brocken Spectre was first noted in the Brocken Mountains in Europe. It appears as an enlarged shadow of the observer on the cloud, surrounded by coloured rings.

The Heiligenschein or Cellini's Halo can be seen on dewy grass as a halo round the shadow of the observer's head.

Scattering

Objects that are much smaller than the wavelength of light, such as gas molecules and fine dust, are able to scatter it by a mechanism (Rayleigh scattering) that affects the shorter wavelengths (blue light) most. Larger dust particles tend to scatter the longer wavelengths (red light) as effectively as the shorter ones.

After rain, when the air has been washed clear of large dust particles, the scattered light appears as a blue sky. At other times, the other colours present make the sky paler. Similarly, fresh cigar smoke looks bluish, but it turns white if it is inhaled first because condensing water increases the size of the smoke particles.

Polarisation

Water waves wave up and down, but which way does a light wave wave? Assuming that a light beam travels horizontally, the electrical vibrations that make the wave can be in any direction across the beam: up and down, left and right, diagonal or a mixture of these. Some substances, including "Polaroid"-type sunglasses, extract from light only those vibrations having certain direction. This action is called polarisation.

Light from the sky is polarised by the various scattering processes that produce it. When it is examined through polarising sunglasses its brightness varies according to the direction in which it was polarised. Meteorological optical effects are accentuated, so sunglasses are recommended for skywatchers.

Miscellaneous

There are many other phenomena of the sky, not all related to the weather, that may need to be considered when a "UFO" is reported.

Meteors leave a streak of light across the sky and may produce fireballs if they reach the ground.

Ball lightning produces reddish luminous balls up to 40 cm in

radius, which behave erratically. They may hover, hiss, smell, explode or just disappear, or even invade houses. They are not well known, partly because witnesses can be scared half to death!

St. Elmo's Fire occurs near conductors in thunderstorms, usually at sea. It may appear as a 10-40 cm ball or as streamers.

Planets may appear to move as clouds pass. At least one star (Betelgeuse) pulsates and changes colour.

Weather balloons come in various sizes. They carry lights when launched at night. GHOST balloons drift around the world at 6, 12 and 25 thousand metres. HIBALL balloons from Mildura expand to 45 metres diameter at great height and can be distorted into odd shapes.

Satellites exist in great number, though they do not stay up forever. All their paths are known and can be identified for the public.

Airport cloud searchlights are used to measure cloud heights. They come on briefly and may appear to move if the clouds are moving.

Vapour trails are produced by pressure fluctuations around jet aircraft. They are sometimes called contrails (condensation trails). The shadows that they cast on clouds can resemble the distrails caused when a jet causes part of a cloud in its path to evaporate. Other contrails caused by condensing exhaust gases tend to be very short.

Nacreous or mother-of-pearl clouds are most often seen in the mountains of southern Norway. They are brightest at sunrise in late winter and appear iridescent. The exact cause is not known. They are at a great height where temperatures are as low as -90°C ; ice formation on frozen sulphuric acid particles has been suggested!

Noctilucent clouds occur about 80 km up, most often at latitudes 45° - 60° in the months May to August. They are believed to be caused by meteoric dust.

Certain air streams, after flowing over an obstacle such as a mountain, can "bounce" several times, sometimes rising to greater heights on the second or third bounce. Wave clouds can appear at the top of each rise, remaining stationary there as if produced by an invisible mountain.

For the UFO-logist....

Mr. Mitchell made some further comments about UFO records which provoked much discussion in the audience.

Meteorological optical phenomena are most common, and at their

brightest, at sunset. It is interesting that most UFO records are made at that time. (A UFO investigator denied that most had used only US records).

Questionnaires designed by investigators and filled out by those who have seen UFOs are very penetrating, but some fail to ask certain important questions. What was the observer looking through? ...Was it plate or plain glass (plain glass distorts)? Wire screen (which diffracts quite well)? Had the observer been looking at a bright object that could produce after-images?

How many UFO records have been credited, to meteorological observers? Surely they are the best trained, most reliable observers around. (This provoked a return question - are observers discouraged from making UFO reports? No - if an observer sees something and cannot describe it in normal technical language he is encouraged to describe it in plain language).

METEOROLOGY FOR PLANNING AT MONARTO, SOUTH AUSTRALIA

Mr. J. Sharpe

Introduction

In much of the world there is a rapidly growing awareness of the role that meteorology can play in planning. Major usages in South Australia have appeared in the Monarto Environmental Impact Statement (Monarto Development Commission 1976), the planning of Port Adelaide (Sharpe (1) 1976) and the North East Area Public Transport Review (NEAPTR 1977). A paper (Schwerdtfeger 1972) has been locally presented suggesting the minimal meteorological inputs needed for planning a city.

However, by far the most comprehensive planning exercise in South Australia has been that for the new city of Monarto*. The aim of this paper is to show the aims of the Commission (which required meteorological input to be achieved) and the monitoring program by which these were achieved. A more general description of the planning may be found in Sharpe (2) 1977.

* The State Government announced recently that it has abandoned plans for a new city at Monarto.

Background

In 1972, the decision to build a new town was announced by the South Australian Government. The city, subsequently named Monarto, was to be on 15000 hectares of generally poor farming land immediately west of the small town of Murray Bridge and to be designed for approximately 180 000 people. The Monarto Development Commission (M.D.C.) was established to plan and build the city, previous land use and planning regulations not being regarded as constraints. The Commission consisted of a team of urban, environmental and social planners, engineers, architects and support staff.

In relation to meteorological assistance, the M.D.C. wished to plan its city so that:

- (1) It would be as attractive as possible, particularly being free of smells and visible air pollution.
- (2) To conserve energy and raw materials.

- (3) To be as pleasant and enjoyable to live in as reasonably possible.

Topography of the Site

The Site is approximately saucer-shaped with a dip to the south-east and is the southern end of an upfaulted block on the eastern edge of the Mount Lofty Ranges. It is bounded by fault lines and scarps on the eastern and western sides, the Ranges to the north and relict sandhills to the south. The main drainage outlet is through Kinchina Gorge, leading directly onto Murray Bridge township. A minor outlet occurs north of this via Preamimma Creek (See map 1.)

First Stage - General Survey

The South Australian branch of the Bureau of Meteorology was commissioned to undertake a general survey of the climate of the chosen site in 1972 (Bureau of Meteorology 1976). The only available records were eight years of temperature, humidity, rainfall and cloud cover from Murray Bridge, a long-term rainfall record from Callington, a short-term record of temperatures from Pallamana (all near the boundary of the site), local farmers' rainguage records and various records from more distant stations in the region. For various reasons none of those could be used as being directly representative of the site but all were considered to provide some guidance.

The types of problems to be resolved are outlined below in the discussion of the results. They can be focused in more detail in Sharpe (1975) and the underlying philosophy in White (1967).

Initial Instrumentation

To provide more data for its report, the Bureau of Meteorology installed four anemographs, a thermograph and four pluviographs as in Map 1. for one year.

Results

The resulting report contained the following sections (each with a guide to the accuracy of the material deriving from the limitations of the data used):

(1) Rainfall.

- (a) Isohyets of median annual rainfall, a decile analysis of annual monthly and daily rainfall and a discussion

upon their variability. This formed a guide to species of plants for home and public gardens, to supply requirements and to possibilities for water catchment.

(b) Rainfall intensity and duration. Used for storm and flood prediction in a separate chapter.

- (2) Temperature and humidity. Various analyses were given of daily and monthly maxima, minima and means temperatures, cold and hot spells, dews and humidity. These were used to analyse variations across the site in daily temperatures and climatic discomfort.

The M.D.C. had formulated a policy of energy and materials conservation. To this end it investigated the design of housing (Thomas 1975) and the basis for this was the climatic discomfort and temperature analysis.

- (3) Sunshine, cloud and solar radiation. This formed a basis for detailed estimations of the possibilities for use of solar energy and also for design of low energy housing.
- (4) Winds were analysed in great detail. The predominant winds were established as being west-north-westerlies (winter), north-easterlies (winter) and sea-breezes (south-south-westerlies, (summer) the data being used for design of shelter-belts and buildings. However, in addition to this, two less usual analyses were presented:

- (a) Katabatic drainage. A comprehensive, detailed map was presented of the direction of flow. As well, an analysis of depth of ponding was made using tethered balloon flights and a general analysis of relative coldness at night over the area of the site was presented, based on nighttime temperature transects. A summary of this monitoring can be found in Robin (1977). The katabatic drainage was used in studies for odour control (Sharpe (1) 1977) whilst the coldness work was used to assist planners to avoid placing housing in particularly cold areas or areas liable to fog.



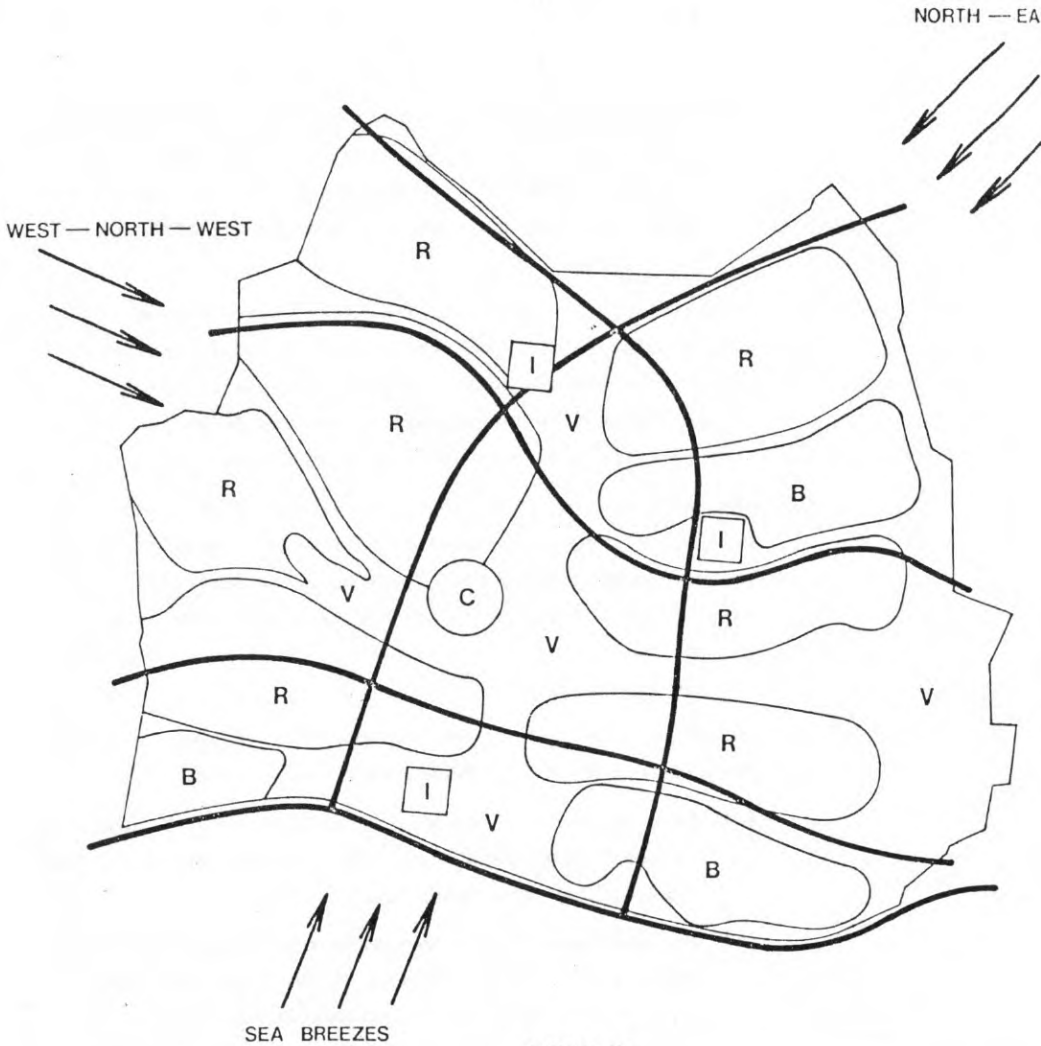
MAP 1

SCALE 1 : 100,000

0 1 2 3 km

TOPOGRAPHY OF THE MONARTO SITE

- (b) Analyses of winds of 6 km/hr or less. This emphasised the winds which are most likely to cause air pollution problems. This was accompanied by an analysis of the daily time and efficiency of breakup of inversions in the area.
- (5) Evaporation. The analysis of monthly evaporation was extremely useful (in conjunction with rainfall analysis) for calculating the possibilities for reuse of treated sewage effluent by large-scale irrigation of pasture and also in estimating water requirements for the city.
- (6) Phenomena such as dust storms, haze, fog, thunder and hail were briefly given to round out the meteorological picture and were useful in general planning. The description of dust and dust storms was very useful in planning dust prevention measures during construction in an area which has low rainfall.
- (7) An interesting section gave a comparison of the climates of Adelaide and Monarto. This served two purposes:
 - (a) To give planners who were unfamiliar with the usage of meteorological data some form of understanding of the figures they were handling.
 - (b) For use in publicity documents and for general public appreciation of the climate of the area. This was particularly valuable as several particular misconceptions regarding the climate were widespread among members of the public.
- (8) Air Pollution Potential. The Monarto project was unusual in that considerations of air pollution were included in the planning, apparently the first planned city in Australia to do so, a lead since followed by other city planners. This chapter included analysis of daily ventilation rates (mixing depth x wind speed) and a guide to critical values, direction of ventilation winds, an analysis of daily Air Pollution Index values (following Miller and Holzworth (1976) and a guide to their significance.

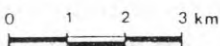


LEGEND

V	vegetation	R	residential
B	broadacre	I	industrial
C	city centre	—	highway



SCALE 1 : 100 000



MAP 2

MONARTO CONCEPT PLAN

- (9) A brief guide was given to the changes which could be expected to the climate of the site due to urbanisation and this was considered in the establishment of a permanent monitoring station.
- (10) Implications for Planning was a chapter of great interest and value. It drew attention to the features of the report which posed particular problems for the planners and suggested direction in which solutions could be found. Unfortunately, the chapter was limited by the policy of the Bureau that it should confine itself strictly to meteorological matters and not venture into planning. This severely limited a potentially valuable contribution and involvement from this specialist area.
- (11) Detailed wind frequency analyses were presented as a separate appendix which provided valuable data for other uses.

General Planning

Some of the above information was used in part of the broad-scale planning:

- (a) Flood plains and katabatic drainage channels were delineated and planned as vegetated areas. These were combined with known vegetated areas and blended into an overall vegetation framework. The climate was then taken into account in selecting appropriate species for planting.
- (b) Building design involved several meteorologically-dependent factors. One was strength of multi-storey buildings which used results from a gust-recorder which fortunately had already been located adjacent to the city site to analyse a possible aerodrome site. A second use was in design of low energy requirement buildings. As well as orientation and width of overhang, calculations were made for cost/benefit relationships for different combinations of insulation of walls and ceilings and different modes and intensities of air-conditioning.

A third consideration was to orient and design the main shopping centre so that it was sheltered from the strong, cold winds and open to the sea breezes. A fourth use was to position major tree plantings for wind-breaks to protect major residential areas. The final use was to ensure that wind speed between buildings in the city did not rise above acceptable levels.

- (c) A major air pollution modelling exercise was undertaken (Strauss 1976). This followed a partly subjective assessment of potential problems by Iverach (1974). After the main plan was outlined, industries were predicted and expected emissions from all major sources were calculated. This took the minimum values of wind speeds which had been recorded as indicative of the worst conditions to be expected.

Second Stage - Specific Monitoring Problems

As the Concept Plan (Map 2) began to evolve, several problems became apparent which required investigation in greater detail.

Coordination

It was quickly decided that economics would forbid the long-term maintenance of many monitoring programs. Therefore a central station was installed to which the results of short-term programs could be related and so some indication of their long-term implications gained (as suggested in Munn 1973). As it would be at least 3-4 years before any development began, air pollution monitoring equipment was not installed although a spot check was taken and a fallout gauge installed.

An incidental use of this station will be to record the effects of the changing land use. The first effect is expected to be cooling, due to the large numbers of trees planted, followed by a heat island effect (Geiger 1950 and Clarke and Bach 1971).

Frosts

Some areas of the site were known to be regularly affected by frosts, with occasional severe frosts. These have implications for home and commercial gardening and road safety.

A network of minimum-recording thermometers was established for one winter, which happened to be a particularly frosty one. This gave an indication of which areas were worst affected and of frequency of incidence (Sharpe (2) 1976).

Use of Rainwater Tanks

Monarto will be dependent upon the River Murray for its water supply and as this varies greatly in quality the water requires treatment of a high standard. Two examinations were undertaken into the expected cost/benefit of the use of rainwater:

- (1) The possibility of domestic usage (Sharpe (3) 1976).
- (2) The possibility of use by commercial/office buildings (E. & W.S. 1976).

These used both the full range of rainfall monitoring described above and generalised return periods for the region.

Both surveys showed that the rainfall monitoring described above and generalised return periods for the region.

Both surveys showed that the rainfall was too low and erratic to be of significant benefit.

Katabatic drainage

Identification of the drainage pattern was undertaken for two reasons:

- (1) To predict transport of odours.
- (2) To locate areas which will be stagnant overnight.

As little finance was available for this it was undertaken through a variety of projects:

- (1) A large internal drainage area exists in the south of the site (See Map 1 Para Gum). This was seen as possibly stagnant or slowly flowing and it was planned to contain an industrial area, sewage treatment works, freeway and possible sanitary landfill. An anemograph was set up at the site of the sewage treatment works. This showed an inflow during the early evening but as the bowl "filled up" the velocity of the air soon dropped below the sensitivity of the instrument (Sharpe (4) 1976). Consequently, anemographs were placed in the position shown as 1, 2 and 3 on Map 1. 2 was on a ridge marking the northern boundary of the basin. 1 and 3 showed that there was inflow and outflow for most of the night on most nights and 2 revealed

that there was negligible flow across the ridge. The conclusions from this were that odours from the depression would be transported slowly out through the gully at 3 and dispersed over agricultural areas and that industrial odours will go north-east into Rocky Gully Creek.

- (2) Small stagnant areas occur in the centre of the site in areas planned for housing. These were located by the Bureau of Meteorology taking night-time temperature transects across the area (Robbin 1977) using a fast - response thermistor.
- (3) A university student obtained an Honours thesis by studying in detail the temperature variations at the junction of the arms of Rocky Gully Creek in the centre of the site. The student studied both surface minimum temperatures and atmospheric lapse rates (Price 1975).

From these three projects and the frost survey, a good idea of the katabatic drainage could be gathered.

Primary Pollutants

Secondary pollutants (i.e. photochemical smog) were not considered to be a problem, due to the low levels of photochemicals found in the Strauss report described above. Odours have been dealt with in relation to katabatic drainage which would be the major meteorological factor in odour problems. This leaves direct pollution by factory chimneys.

The southern industrial area is the only one whose position is known accurately, and due to its position it is likely to have the lowest wind speeds. Therefore an anemometer was placed in the area, approximately to the standard height, for one year. The results from this will be used to give approximate values for dispersion parameters in future mathematical models for each major source used to ensure that ground level concentrations of pollutants remain within acceptable levels.

Inversions

For all future air pollution work, more detailed data will be needed on meteorological parameters. The main station will give a good indication of wind speed and direction but data on mixing height was totally lacking.

Again, this was provided by a variety of methods:

- (1) As part of the investigation of the southern depression, a 30 metre mast was set up for several months with temperature sensors along its length. This showed the time of formation and rate of rise of katabatic ponding in the southern industrial area. It also revealed a very steep lapse rate.
- (2) The same mast was used by Price as mentioned above.
- (3) A class of Geography students monitored many meteorological factors, including lapse rate using the mast, for four days.
- (4) A student is endeavouring to obtain a Master's Degree on inversion levels over all of the site by using this information, further use of the mast and use of an acoustic sounder. It is hoped that this will give a reasonably complete picture of inversion levels.

Conclusions

A number of conclusions spring from the experience gained in this exercise:

- (1) A properly planned and managed meteorological monitoring program can provide a large amount of valuable information for a very reasonable cost.
- (2) The program must be systematically organised and carried out by qualified officers.
- (3) A period of several years, preferably 5-6 years, should be allowed for monitoring before planning begins.

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NEW FIELDS IN ASTRONOMY

Dr. A.T. Beresford

A report of the November meeting, as recorded by R.J. Whatmough

Astronomers today are not restricted to what they can see in the sky. Their instruments can study all kinds of radiation from short-wavelength X-rays to long-wavelength radio signals.

Large conventional telescopes have greatly improved. The modern instrument is as precise as the best lathe. It is controlled by computers which point it at any desired point in the sky, making all the necessary corrections. The modern astronomer doesn't need to ride on the end of his telescope unless he is changing photo plates - he watches on a TV monitor on the ground.

Radio signals are received using large metal reflector "dishes". For a single dish, the resolution obtained is improved only by making the dish larger. At Culgura, near Narrabri in New South Wales, radio astronomers have cheated by building a row of dishes wired together. These give a resolution of 2' of arc at low frequencies and are used for studying the sun.

When the sun is studied optically, astronomers often use filters that pass certain wavelengths emitted by glowing hydrogen but absorbed by cooler hydrogen gas. Gas clouds near the sun show up as black patches when seen through these filters. Solar flares, the most energetic events in the solar system, also show up well this way. Sunspots, which were once thought to come in 11 year cycles, have been studied further and now seem to have a 10 year cycle. (A member of the Bureau staff noted later that our weather has no such cycle - it is not affected by sunspots).

Photos taken during solar eclipses allow us to study the outer part, or corona, of the sun. The corona is unstable, so some matter is escaping all the time. This matter forms interesting patterns as it is guided by the sun's magnetic field. The corona is believed to be heated by sound waves - rumblings from below!

Jupiter has always been mysterious to astronomers. It is shrouded in cloud belts which are drawn out by its rapid rotation,

one turn every 9-10 hours. For over 100 years it has displayed a large red spot, whose nature is not fully known. The spot moves with the planet's rotation but not always at the same speed. It varies a little in latitude and a lot in longitude, so it must be in the atmosphere, not on the planet's surface. When it moves faster, it is harder to see, so it is probably lower in the atmosphere. Jupiter is so large that, unlike the earth, it is emitting more radiation than it absorbs. It has been suggested that heating from below could keep a cyclone going in the atmosphere for centuries, and that the red spot is a long-lived cyclone.

Spacecraft have photographed four moons near Jupiter, as large as our own moon but with different structures. An aurora was recently seen in the planet's atmosphere - it was apparently related to the magnetic effect of Io, one of the moons.

Astronomers get much of their information about the properties of stars by photographing their spectra. Photometers can add useful measurements of invisible radiation. If the measurements are summarised in two quantities, one for 'colour' and one for 'brightness' there is much to be learned. For most stars, the brightness is related to colour in a definite way. Such stars are called 'main sequence' stars.

It is known that main sequence stars are those that are converting hydrogen into helium, like our sun. They differ only in their masses - the heavier ones are converting more quickly and are bluer and brighter. It has been predicted that a star with more than 60 times the sun's mass cannot exist - it would blow itself apart.

Before the hydrogen-to-helium reaction starts, a new star is invisible but the heat produced by condensing matter can be picked up by infra-red telescopes. Photographs produced by these show a "cocoon" of dust (mostly ice, graphite and silica) which is collapsing but which will eventually be blown away to reveal the new star. The presence of dust is essential for the birth of a star - it protects the centre from the pressure of radiation from other stars.

When a star runs short of hydrogen, other reactions can keep it going for a time, depending on its size, but eventually it will die in one way or another. The end is dramatic, and the large energies involved produce X-rays which astronomers can detect. A star about the size of the sun expands to a "giant" (the sun could do this in

about 5000 million years' time) then collapses to a "white dwarf". Such a white dwarf is orbiting around Sirius now - it has the same mass as the sun but only 1.6 times the diameter of the earth. White dwarfs keep going only by converting hydrogen that happens to fall into them.

In stars more than 4-5 times heavier than the sun, various nuclear reactions finally convert everything to iron. Iron is the most stable element (it cannot be changed into anything else by a further reaction) so the fuel runs out very suddenly. The star collapses in about a day. The heat at the centre then explodes the star. The watching astronomer sees the surface suddenly begin to expand at 100 km/s. There is no change in colour for another 60 days or so, but then the star becomes very bright, often brighter than all the stars in the rest of its galaxy combined. The expanding gas cloud can be detected centuries later, still faintly glowing as it hits stray atoms in space, though by then the gas is very thin indeed. The well-known Crab Nebula is the remnant of a star that exploded this way in 1054 AD; part of its glow comes from electrons that are gyrating in a magnetic field. In its bright stage, such a star is called a "supernova".

In the Crab Nebula there is also a pulsating radio source or "pulsar". The radio telescope cannot fix its position exactly, but its signals can be used to open a camera shutter at the same point of many successive pulse cycles. When photographs prepared this way at two different points in the cycle are compared, a certain star appears in one but not in the other. This star is flashing in time with the radio pulses and must be their source; it is probably a fragment of the supernova.

Another kind of "dead" star is the neutron star, in which all matter has been squeezed into a clump of neutrons.

When a star is moving away from us, the wavelength of all its radiation appears decreased to us, so that its light appears redder. This effect is called "red-shift". Generally speaking, other galaxies are moving away from us, the further ones moving faster and showing greater red-shift. Somewhere among them are the "quasars", which emit radio signals in bursts. The radio signals have been affected strongly by red-shift, but the signals are not weak, so quasars must be distant

but very energetic. The short length of the bursts is evidence that these bodies are quite small despite their energy.

The Pleiades (or Seven Sisters) are a cluster of stars in the northern sky. They formed from a collapsing gas cloud too big to form a single star.

Most galaxies have the familiar spiral shape but there is another shape called the "globular cluster". Galaxies of this shape seem to be concentrated in one area of the sky. It has been suggested that they mark the original centre of the universe.

Astrophysicists like to study gas clouds. They can do this when radiation from nearby stars is absorbed and re-emitted by a cloud. From the microwave radiation, the chemical composition of the cloud can be deduced. Unexpected substances like alcohol have been detected. It is unlikely that such a substance could be formed by random collisions of atoms; perhaps some atoms attach themselves to dust particles which hold them until others arrive.

The North American Nebula, shaped like its continental namesake, includes some very bright cloud patches which may be stars that are forming by some process that does not need the usual "cocoon" of dust.

The British Interplanetary Society has mooted sending a probe to another star. Such a probe could be expected to travel at about one tenth of the speed of light, so it will take at least 40 years to reach the nearest star. The main difficulty with such a project would be to keep the scientific team that launched it, together for the next forty years!

COMFORT AND HOUSING

J. Kerby

A report of a meeting as recorded by R. J. Whatmough

Mrs. Kerby has been studying the climatic suitability and energy requirements of houses, for a Ph.D. thesis, for over 12 months. Her findings could have an important influence on future housing design if they can be suitably presented to the public. Her subject includes human comfort in different types of houses in extreme weather conditions.

Houses were studied in sample areas from Unley to Somerton Park and at Elizabeth East, so that a range of ages was covered, but houses close to the sea were avoided. Each 20th house on aerial photographs was chosen for visits and owner interviews. Estate agents all over the metropolitan area and building designers in the City and south-western suburbs were interviewed.

An interesting succession of house styles was revealed in the study. In the middle of last century, there were many bluestone houses with verandahs at the front and corrugated iron roofs. There were also villas with shuttered bay-fronted windows at the front. After 1880 verandahs spread to the sides of houses. After 1890 a small louvred vent at the top of the roof became fashionable.

At the turn of the century, houses became more ornate and the sides tended to be built of brick. About 1910 the first tile roofs appeared. In 1918 the "bungalow", a heavily-modified Californian design, arrived. Sleep-outs on the front verandah became more popular. Some verandahs became wider - this gave darker, cooler rooms and required more lighting.

From 1935 to 1945 there was the Tudor style, with steep roofs originally used to allow the snow to slide off. After 1945 came the "austerity styles" - brick, corrugated iron roofs and no verandahs. Tiles returned, and the overhang of eaves increased. From 1950 there was more affluence; complicated shapes and large sliding windows (especially aluminium) appeared.

Since 1970 we have had many very large windows and low-pitched roofs. Some designers have sensibly used smaller windows and have dared to turn blank walls to the street - most prefer good looks from the street.

Comfort is subjective, of course, but people have tried to set down ranges of temperature and relative humidity for various parts of our daily lives in various seasons. "Temperature" as used here is not the dry-bulb variety but a modified kind that takes radiated heat into account.

For summer living, humidities 30 to 80 percent and temperatures 20° to 28°C are suggested. If the air is moving, temperatures can go up to 30°C . For winter living, the temperature range is 19° to 22°C . For sleeping, humidities 30 to 70 percent and temperatures 13° to 24°C are "comfortable". The human body tends to adjust to the prevailing conditions, but lags 2 months behind the seasons.

The survey looked at the siting and orientation of houses, their materials, shading of houses by themselves, eaves and trees, the size and placement of windows, cross-ventilation and draughts, provision for private outdoor living, ceiling insulation and the use of artificial heating and cooling (a desperate last resort!). Comfort in summer and comfort in winter were considered separate features of a house.

Eaves that face north, if the right size, can keep the hot summer sun off the windows but let the warm winter sun in. Eaves on the west side can be useless, like the decorative window shutters found on some modern houses (they won't shut). Awnings and deciduous vegetation, which can shade in summer only, also help. A shelter over the door helps the entry of people in rain. Combined wind-rain statistics show that the main rain-bearing winds in Adelaide are west, south-west, south and north-east in June, and west and south-west in January.

How hot are Adelaide summers? From Bureau statistics, we can look at the number of days each year with maximum temperatures over 100°F , and the number of times that the maximum was over 95°F for the third consecutive day. Either way, the years 1920 to 1940 were hotter than average, and later years have been milder with about half as many "hot" days. There is a catch - after 1948 the Bureau used the modern Stevenson screen for its thermometers. Before 1948 the Stevenson screen and an older type were used side by side. Thermometers were placed in seven houses in the survey, sometimes in two or three rooms for comparison. This exercise was done in March, when air conditioners

are little used. The results showed that temperatures may vary greatly between rooms in the same house. In one house, a sunroom was too hot on summer days, but pleasant on winter days and a good place to sleep on summer nights (the wall materials allowed rapid cooling).

Householders were asked how satisfied they were with the size and placement of their windows, daylight indoors, air movement, outdoor living facilities, room temperatures, shade on the house and its cooling abilities. There was much dissatisfaction with temperatures, and people demonstrated this by installing sunshades, air conditioners and insulation within a few years of moving in. Some also installed window tinting - which doesn't help much in winter.

The most popular heating methods are first, gas and second, oil. Electricity is a long way down the heating popularity list. When the main heating methods used in houses were matched with energy consumption, the oil-heated houses were found to consume most, much of it in electricity. Reverse-cycle air-conditioned houses came next - they used an efficient heater, so the owners must have heated many rooms in their houses. Open-fire and kerosene-heater houses came lowest in energy consumption. The latter also used least electricity perhaps these were where pensioners lived.

Certainly income has a strong influence on energy use. The survey found houses well-designed for our climate with lots of heating equipment, and others poorly designed with very little. When the energy uses of houses with and without insulation were compared, surprise! The insulated houses used more. It seems that people who are unhappy with their cold houses buy insulation and heaters together.

What do people look for when they buy houses, The survey revealed that "climatic suitability" came last in a list of features. And who designs Adelaide's houses? Some 68% were designed by commercial builders. Another 10% were designed by building design firms, and 9% by "public-sector" architects (as might be employed by the Housing Trust).

Do massive stone houses absorb too much heat? Bluestone is good in summer, but absorbs the heat from your heater in winter, too. Cavity brick does better in summer and winter, but a lightweight

sleeping area is suggested, for rapid cooling on summer nights.

Can an attic be a heat trap for winter? Yes, but a smaller air space would be almost as good. It is hard to balance the summer and winter effects of this sort of "insulation".

Does a solar water heater help? Solar water heating is very trendy - when you have it, everybody knows you have it. It pays for itself, but takes a long time to do so, so if you are at retiring age, don't bother!

Do concrete floors help? A concrete floor is a good heat stabiliser. It works best if it is uncovered where the winter sun strikes it, and covered with a rug at night. Bare concrete may not be good for babies, of course.

Members of the audience reported that skylights let in a lot of heat, and that some Canberra houses are effectively heated by wires set into their concrete floors.

ICEBERGS AS FRESH WATER SOURCES

P. Schwerdtfeger

Flinders University

A report of the June meeting as recorded by R. J. Whatmough

Professor P. Schwerdtfeger spoke at the June 1979 meeting on new and not-so-new uses for icebergs. He has served on a small national committee that studied the subject recently.

The committee members recognised that the Murray River would not supply enough water if present population trends continue and we use water the way we do now. A major part of the problem is the loss of water by evaporation in various ways. (We can, of course, try to reduce water consumption by changes to our way of life, such as the use of less-thirsty native plants in our garden).

In Adelaide, we let the catchments in the Mt. Lofty Ranges be destroyed. It is too late to reverse the change now - too many people live in the Hills. Is the Murray the only source left to us? There are several alternatives.

We could try piping water from interstate, or bring it here in tankers. We could desalinate sea-water - the CSIRO is investigating this method now.

We could indulge in "meteorological engineering", like the company that once investigated spraying a large basin with tar, so that the heat trapped there would cause uplift and ultimately rain. Seriously, though, we are not yet willing and able to manipulate the weather reliably.

Finally, we could tow icebergs in. This is a very neat alternative, for an iceberg needs no packaging.

In cities, "excess water" costs about 10¢ a cubic metre. If we are to try new water supplies without upsetting the economy, they must not be much more expensive than that. We can quickly discount the possibility of using tankers. There is a project to set up a tanker post on Reunion Island. Fresh water would be supplied from Europe as ballast in some of the tankers. It has been estimated that this water will cost 45¢ a cubic metre.

Middle East countries have a lot of money and not much water. They want their supplies to be "politically viable", so there is no chance of buying from a certain neighbouring country. The present method is therefore tankering at 90¢ a cubic metre. There is also a religious taboo on charging for God-given gifts, so water is distributed without any charge beyond the cost of local cartage.

Somebody has suggested the use of plastic bags instead of tankers to transport fresh water by sea. They will float, and the plastic is cheap, but, when bags big enough to supply Adelaide with 0.16 cubic kilometres a year are considered, it turns out that the pressure inside requires walls as thick as tanker walls to contain it. So the plastic bag is not really cheap at all.

Towed icebergs were used as a water supply in Chile last century. In 1969 the Americans suggested this as a 20th century source.

Where can towed icebergs be most useful? Most deserts are in sub-tropical zones and extend from the west coast of a continent. There are many more icebergs in the Southern Hemisphere than in the Northern. So the west coasts of southern continents would seem to have the most use for them. The relevant countries are Chile, South West Africa, where technology is lacking, and Australia, a wealthy and politically stable country with plenty of engineers.

Newspaper and scientific journal articles scoffed at the idea of towing icebergs until the Arabs showed an interest. The Prince of Saudi Arabia asked 20 scientists to evaluate claims that bergs could be towed straight to his country. They reported that the claims were premature and suggested that the scheme to be tried first in south-west Western Australia.

Antarctica has a mean annual precipitation of 13 cm. This represents the equivalent depth of water - the snow itself is more than a metre deep. The actual precipitation varies from 5 cm in the centre of the continent to 60 cm near parts of the coast. The weight of later years' falls expels air in the snow or causes it to dissolve, and ice is formed.

As more snow is added on top, ice is forced over mountains into the sea where it forms "ice tongues". These are up to 250 metres thick in parts of the Ross Sea. When they break up at sea, they form

icebergs. The snow that falls is enough to supply ten thousand million people with a water supply, if they use as much as average South Australians. So long as the icebergs carry ice away as fast as it forms, there will be plenty of water for all, and we need not upset the "balance of nature" or fight each other over its use.

How big is an iceberg? 50 years ago, a Russian scientist collected statistics on the sizes of icebergs all over the world by searching ships' logs. His graphs showed that their mean length was about 1 kilometre, that their height was 40 metres.

From satellite photographs of the oceans near the Antarctic coast, we now have more detailed statistics. Near the coast the mean length is 700 metres; further away the lengths tend to be near 700 metres or near 350 metres. Apparently icebergs prefer either to stay in one piece or to split into two. Probably the best kind to tow is a big one far from the coast, for it has proved its capacity to stay in one piece.

How much of an iceberg shows above water? The answer depends on the density of the ice, and the density varies from top to bottom with the age of the ice, reaching 80% of that of water when trapped air has been broken into separate spaces and 92% in pure ice. Typically, an iceberg 160 metres high shows 20% above water, while one 260 metres high shows 17% above water. The difference between separate and continuous airspaces is also very important for another reason. If the zone of continuous airspace extends below the waterline, the ice can be contaminated by salt water. Only icebergs from certain parts of the Antarctic coast are suitable for fresh water for this reason.

Temperatures within an ice shelf start at about -20°C at the surface, fall slightly inside the ice, then rise rapidly to 0°C towards the bottom where the ice is melting.

Surveys of iceberg numbers around Antarctica have shown that the average distance between icebergs increases rapidly to about 16 kilometres at 240 kilometres from the coast, then more slowly. They encounter water temperatures which rise to 0°C at about 65°S , remain below 2°C until 50°S , then rise rapidly. (These temperatures are averaged over depths up to 200 metres). The most likely places for icebergs to finally disappear are around 46°S .

A well-chosen iceberg could be expected to take 300 days to melt under tow. The trip to Australia would take about 100 days and about 40 metres of ice would be lost in this time.

The sun alone would take 20 years to melt the same iceberg. So what goes wrong? Sea waves tend to cut caves in the side near water level. The ice above the caves collapses, and a ledge forms and grows into a conspicuous feature. Similar processes go on below the water. French iceberg-ologists have invented a "belt" that wraps around the sides of a berg and reduces melting by preventing cave formation.

Studies of towing techniques suggest that icebergs would be towed at 1 knot. This is not so bad when they are travelling around the clock. It will take a quarter of a day to pick up this speed and longer to stop again. Much planning will be needed for the tow. Exactly how the towing is done still has not been decided. There are many proposals, the biggest problem for any method being the rough seas common to our south.

The next problem facing the captain with his chilly cargo is where to take it. An iceberg approaching Australia would have a depth near 180 metres. Since our continental shelf is only 200 metres deep at the outer edge, we cannot expect to bring an iceberg close to the coast. The nearest we could manage is 22 kilometres from Rottneest Is., W.A., or 30 km from Cape Banks near Robe.

Melbourne has had water problems (it nearly ran out in 1966) but there is more water north of the Great Dividing Range if state political problems are overcome. Perth has a greater need - it is growing faster and has used all the sources that are available to it without severely reducing open space areas for its residents. Furthermore, bauxite mining nearby has spread the fungus *Phytophthora*, which kills jarrah trees and makes the catchments saltier.

A cubic kilometre of ice, at 10¢ a cubic metre, would sell for \$100 million. That's a very exciting sum for anyone who is interested in starting a towing business. But the heat that the ice can absorb in melting makes it worth ten times as much if it is used as a source of energy or to make other sources more efficient (for example, as a coolant in power station condensers). Icebergs could supply 20% of W.A.'s power.

When the iceberg arrives off W.A. (or Robe), then, it would be broken up, and the pieces would be taken by shuttle tanker to power stations. The melt water would go to the reservoirs.

Australia passed up an opportunity last year to further iceberg research at little cost. We could have put a radio transmitter on a berg and had it tracked as part of the GARP experiment. Unfortunately we needed the money for other things, so now the Norwegians are doing the experiment.

Prof. Schwerdtfeger had some further interesting facts at question time. An iceberg that has sufficiently reduced its length and width becomes unstable, despite the higher density at the bottom, and is likely to roll over.

Currents in the Southern Ocean run at about $\frac{1}{2}$ knot, so if we tow at 1 knot we must travel with them.

A berg with a fifth of a cubic kilometre of ice will half melt in towing but it is still well worth bringing.

We can expect that a berg will be "X-rayed" with radio waves to detect major fissures before it is taken in tow.

There will be costs to both sea life and to man in towing icebergs. Some sea creatures will follow the cold wake of the berg and find themselves stranded in temperate waters. The sea floor will be damaged to some extent, and there will be some loss of fish. But the sea temperature will not be affected beyond 5 kilometres, and weather on land will not be influenced.

The first tow could easily cost Australia \$2 million - but the profits would be high. We have already spent \$ $\frac{1}{2}$ million just talking about icebergs!

EXTREME RAINFALL

K. Burrows

A summary of an address to the Association, as recorded by J. Whatmough.

A new record was recently set for daily rainfall at an Australian recording station. 1140 mm were recorded at Bellenden Ker, Queensland, in the 24 hours ending at 9 a.m. on 4th January, 1979. The previous record was 907 mm, also in Queensland, measured on 3rd February, 1893.

The station is 1500 m up in the Bellenden Ker Range, which runs from near Cairns to near Innisfail. The ground here slopes steeply (1 in 3) down to the south-east. Charts show that Tropical Cyclone 'Peter' approached the coast from the north-east on 1st January, crossed it, moved eastwards back to sea on the 2nd then decayed to an active rain depression over the next 3 days. The dying cyclone brought winds of 60 to 70 km/h, with gusts to 120 km/h, to Cairns, and carried moist air up over the range. Another 807 mm were recorded for the 5th.

Between the 8th and 10th, another Tropical Cyclone 'Greta' moved from the Gulf of Carpentaria to the Coral Sea, bringing heavy rain to Cape York Peninsula. This helped to set a monthly rainfall record, 5387 mm at Bellenden Ker, for January 1979, the previous Australian record being 2988 mm for February 1883.

For comparison, Adelaide's daily rainfall record was 141 mm on 7th February 1946. For South Australia, the record was 222 mm at Stansbury on 18th February 1946. The world daily record was 1870 mm (some shower!)

Adelaide's monthly record was 218 mm in June 1916. Mt. Lofty managed 456 mm in the same month. 9300 soggy millimetres were once recorded in one month in India.

One problem in recording Bellenden Ker's rain would have been the size of the gauge. Most in Queensland hold about 200 mm, so someone must have half-drowned five times in one January day in 1979.

